Verification studies with Tempest

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What is the ESL?

edge simulation laboratory

- ESL = Edge Simulation Laboratory
  - Project to develop an edge gyrokinetic code using continuum [evolving f(x,v) on a 5-D mesh] methods
  - OFES/OASCR base-program activity
  - Collaboration: LLNL, GA, UCSD, LBNL, CompX, Lodestar, PPPL. Others welcome.
- Present projects
  - TEMPEST code (outgrowth of LLNL LDRD project; full geometry, full-f, E-μ finite difference.)
  - EGK: prototyping code, $v_{||}$-μ, simple geometry; finite difference; presently linear
  - Next generation: high-order finite volume, fully conservative, $v_{||}$-μ, full geometry (construction begun)

TEMPEST CODE

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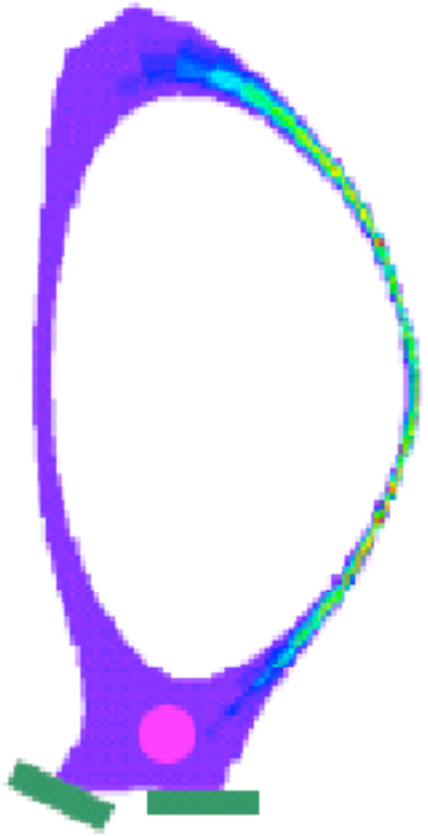
- 5D (ψ,θ,ζ,E_0,μ); results here 4D
- Geometry options:
  - Shifted circle core
  - Full single-null diverted, closed-flux-surface + SOL
- Implicit backward-differencing time advance Newton-Krylov iteration
- 4th-order finite-differencespatial discretization
- Low-order finite-volume discretization for collisions
- Collision options
  - Krook
  - Lorentz with full v dependence
  - Full collision op. with test-particle or fully nonlinear Rosenbluth potentials



1D-2V: TEMPEST recovers theoretical endloss results with modest v-space resolution (linearized collisions)

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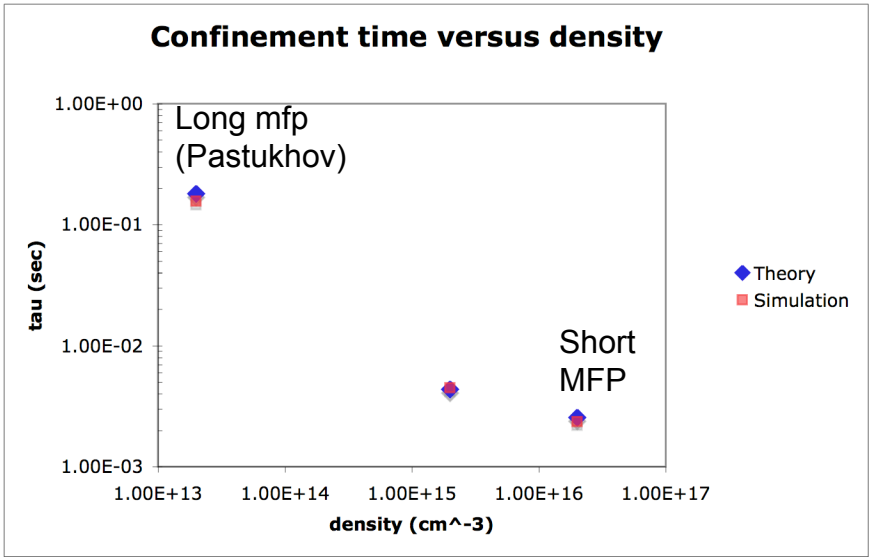

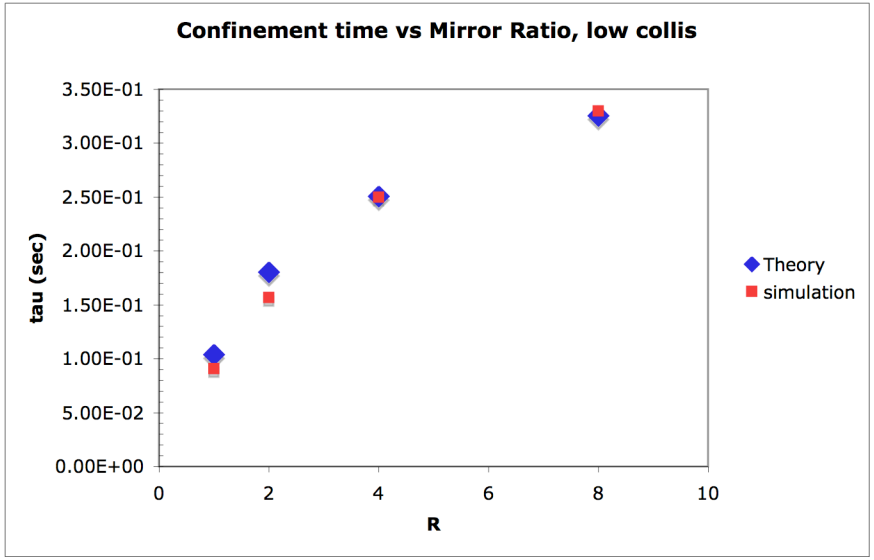

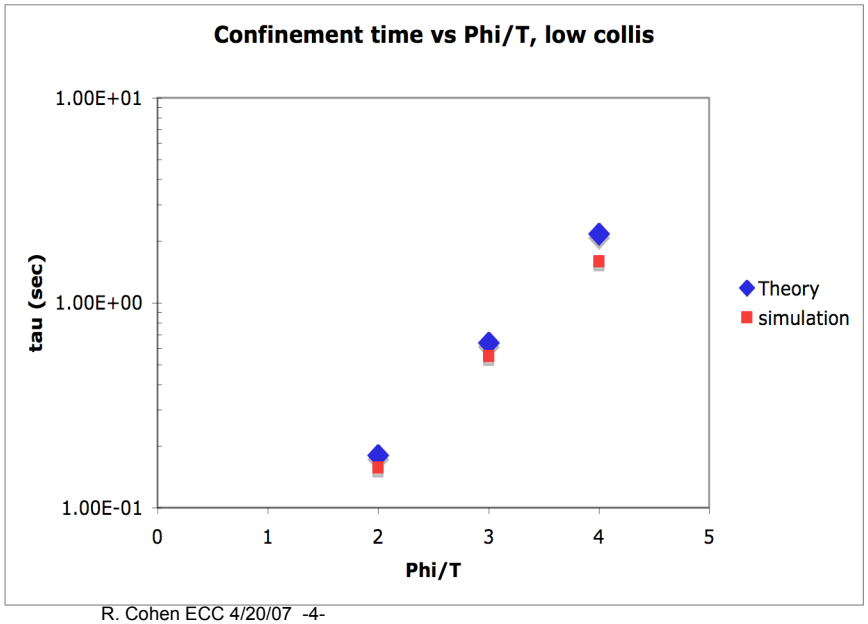

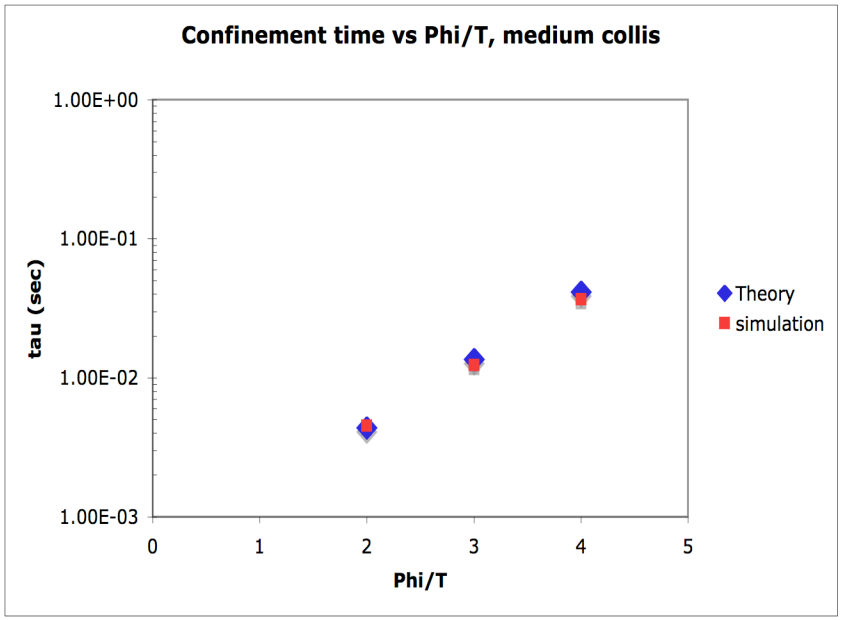

Neoclassical tests

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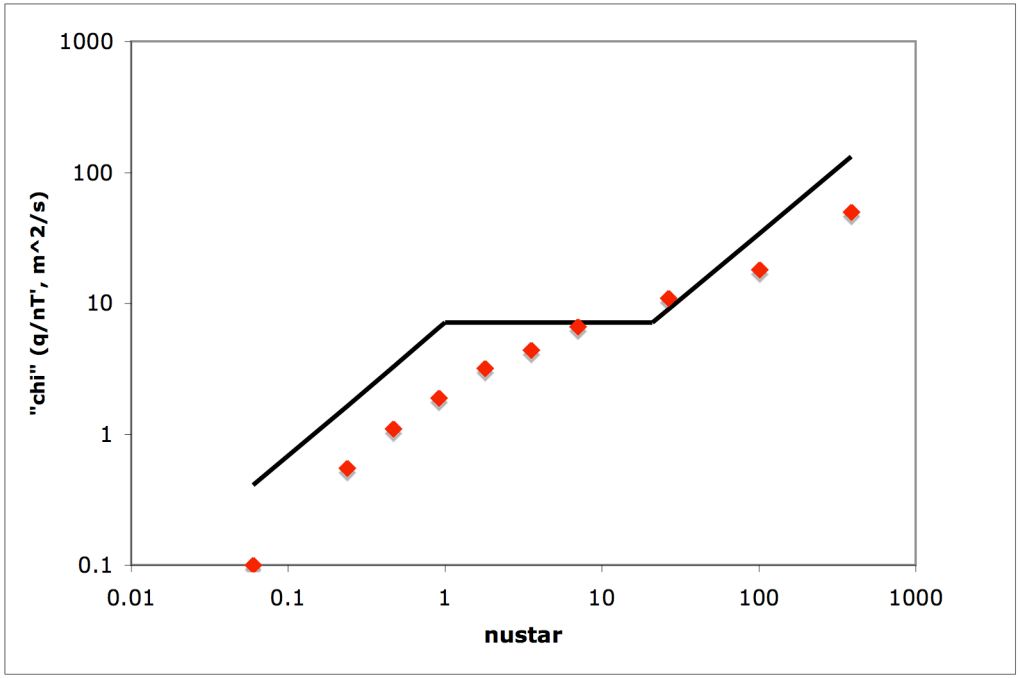
- Tests done using Krook and Lorentz models; will show here results from Lorentz
- Tests done with both available geometries (circular ring and divertor)
- FULL f (not delta-f)
- Steady-state problem definition:
  - specify f=Maxwellian with prescribed n, T on inner and outer boundaries where drift is into domain
  - Specify no returning flux at divertor plates for divertor runs

ν^* scan

- Circular geometry, annulus, weak gradients (10% n and T variation over annulus)
- Lorentz collisions, full-v dependence
- No E field
- Npol*Nrad*NE0*Nμ = 30*36*25*44
- Compare to expressions derived by Lin
  - Lin: derived for const ν.
  - Comparison done with ν from NRL tables temperature isotropization



Comparison with XGC: core slice

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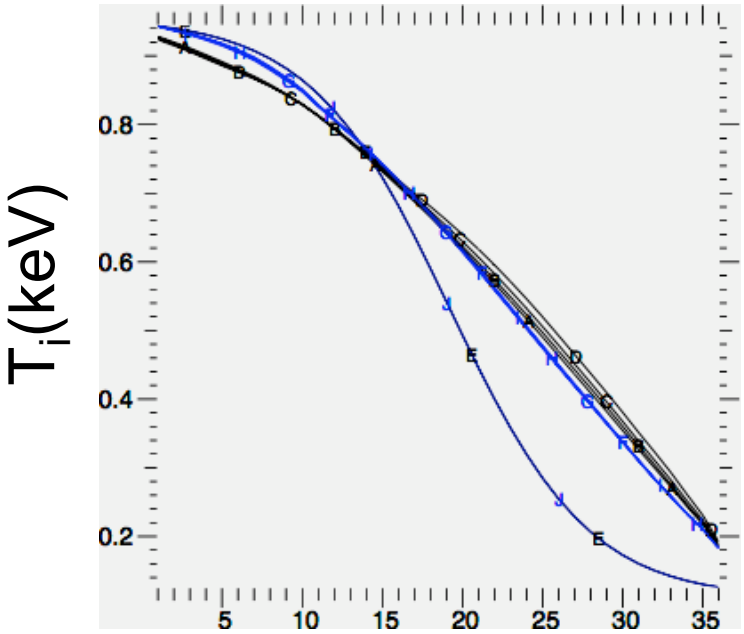
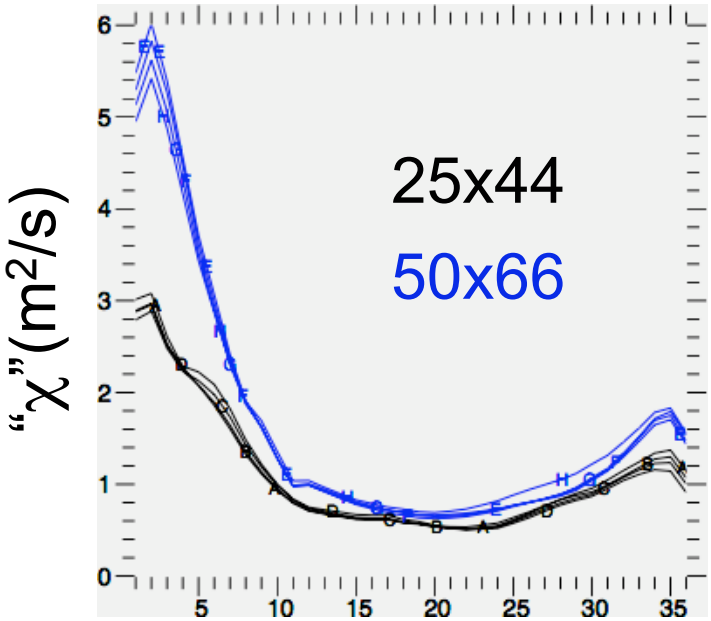
- Core annulus from ψ_N = 0.4 to 0.6
- Steep T and n profiles: T_i varies from 1 keV to 100 eV; n varies from 5e13 to 5e12.
- Lorentz colllisions, no potential
- Caveats:
  - TEMPEST run with circular flux surfaces, and collision frequency evaluated with n and T from initial profiles
  - XGC run with EFIT flux surfaces, n and T for collision frequency updated occasionally
  - Preliminary. These runs were done in the past week.

Convergence w.r.t. v-space resolution

edge simulation laboratory

- We were concerned that our relatively coarse v-space grid would be a problem at low-temperature end of simulation
- Comparing runs at different resolutions suggests that the convergence is quite good within interior of domain.





Comparison with XGC: divertor NC simulation

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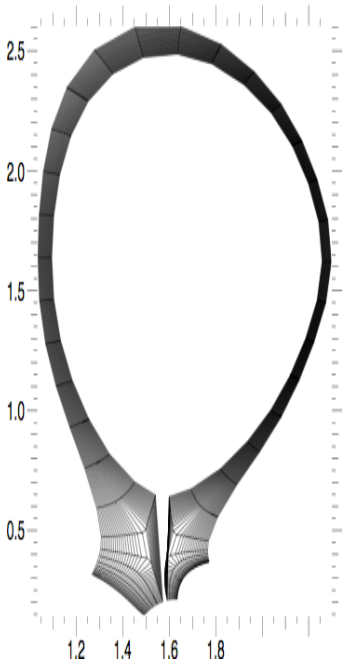
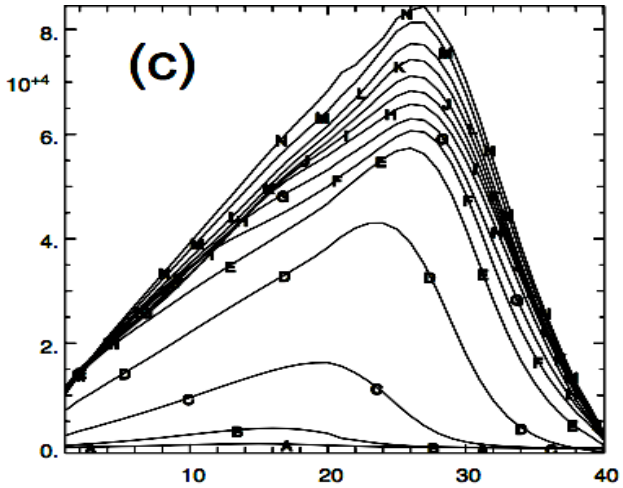
- Simulations based on common EFIT files
- Tanh initial T_i and n radial profiles, centered at $\psi_N = 0.99$, half width 0.02; $T_{i,max} = 1$ keV, $n_{i,max} = 0.5 \times 10^{14}$ cm^{-3}; T_i, n_i min 0.1 times max. Poloidally constant on separatrix.
- For Tempest: resolution npol*nrad*nE*nμ = 50*40*40*50
- Caveats:
  - Different versions of Lorentz collisions:
    - Tempest run is with Lorentz with constant n and T (= values at inner bounary).
    - EGK run is with Lorentz with local (and periodically updated) n and T.
  - VERY preliminary. These runs were done during TTF. 1st run-of-kind for TEMPEST.

Results

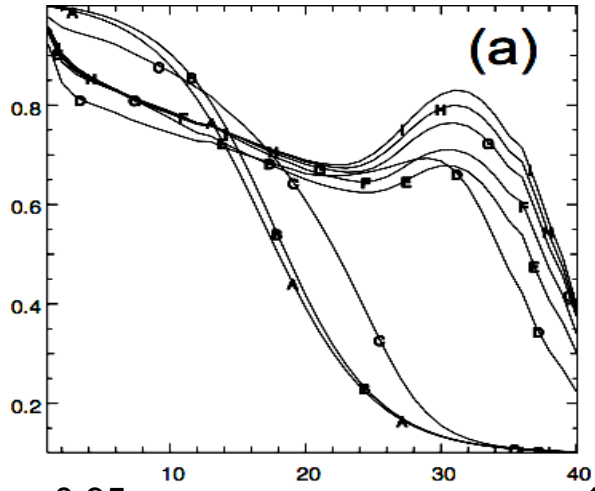


$-u_{||}$ (m/s, pol av above xpt)



ψ_N=0.95 ψ_N=1.0 ψ_N=1.05

T_i (keV, outer midplane)



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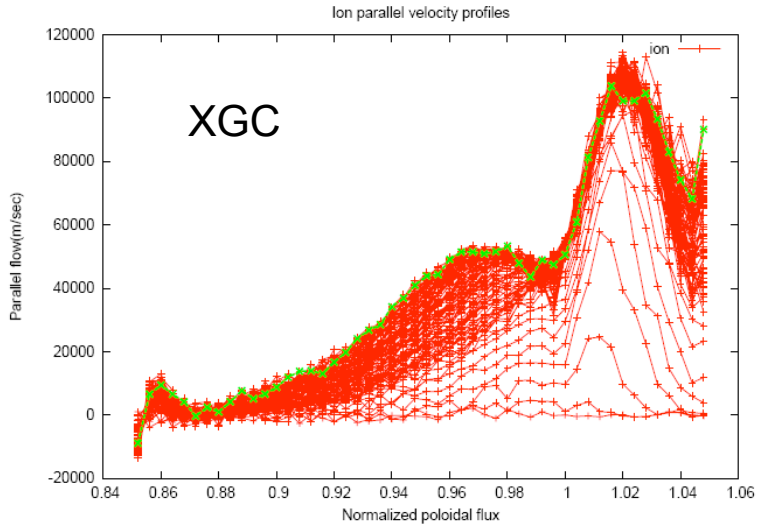
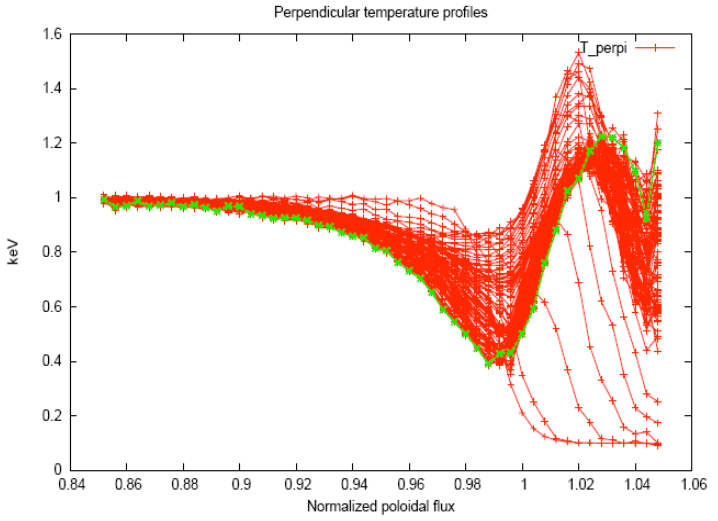
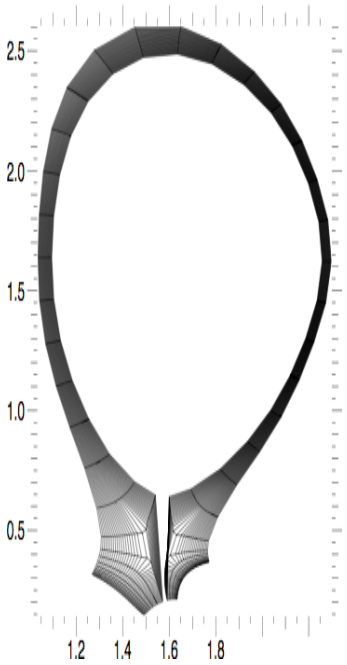




Results

edge simulation laboratory



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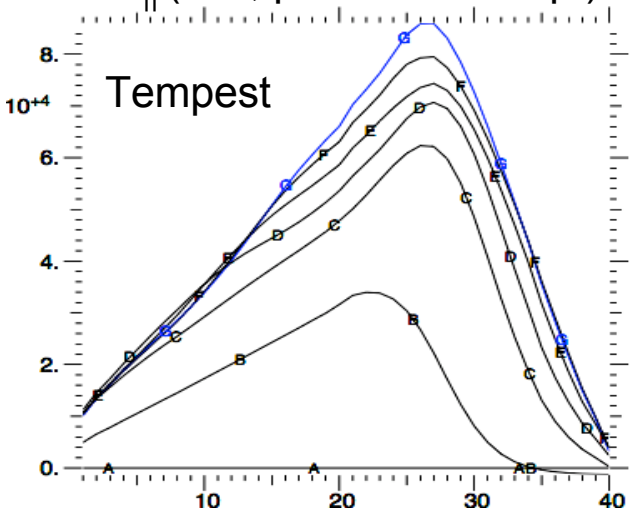

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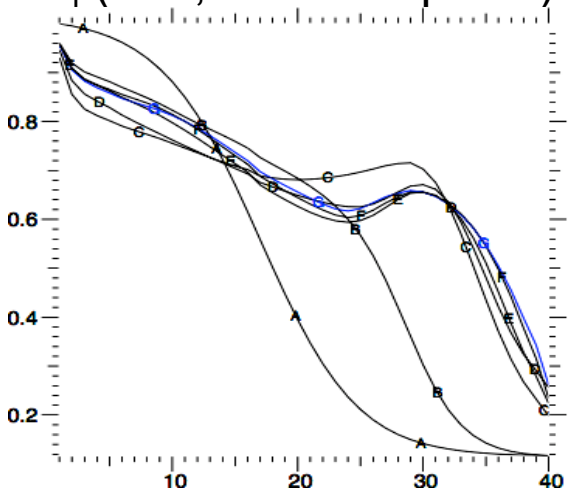
T_i (keV, outer midplane)



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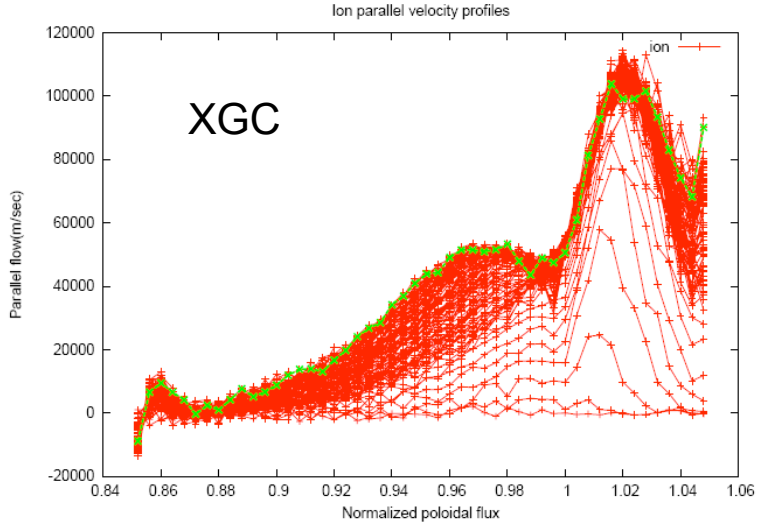
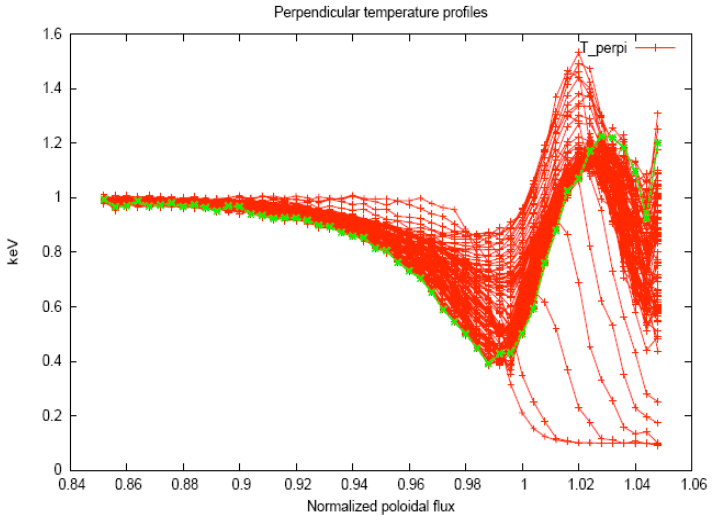
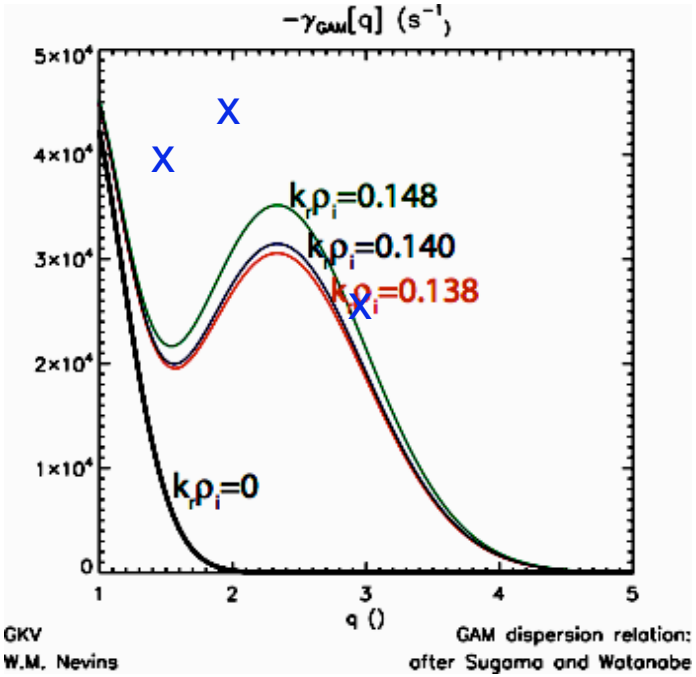




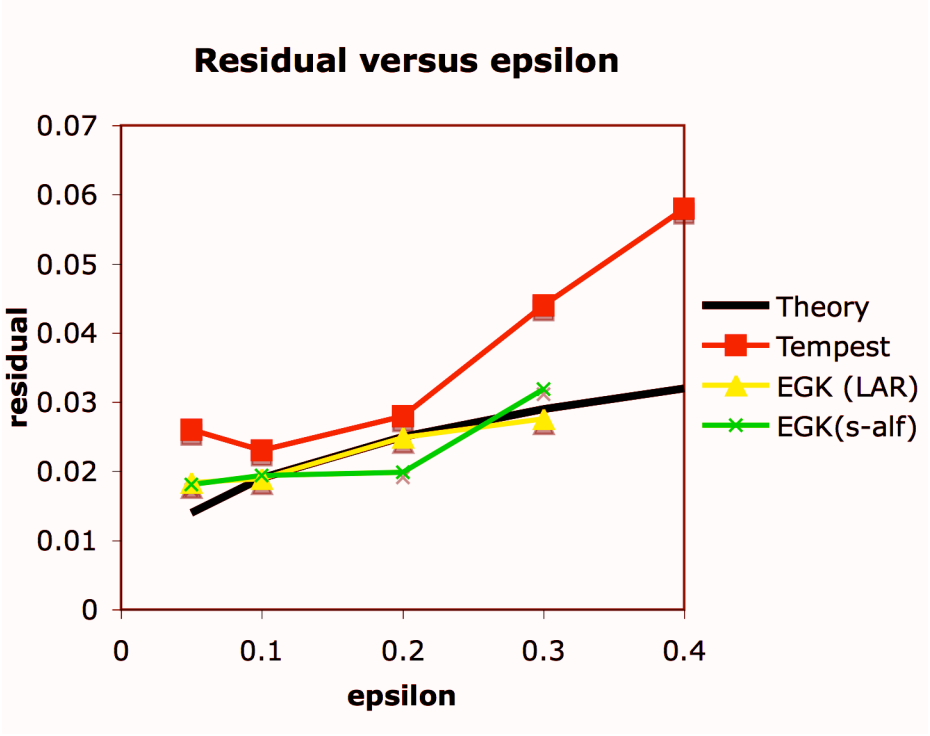
Postscript on GAM tests

- Since Wed. more GAM cases at different q's have completed.

x



x



* EGK results courtesy of E. Belli, J. Candy, P. Snyder

Conclusions

edge simulation laboratory

- Initial comparisons are encouraging
- Further tests with XGC, EGK, and other codes will follow
- Planning to return to 5D tests (started last fall) in next month
- Equally as encouraging as the positive technical results is the positive cooperative spirit between the ESL and CPES teams. (Thank you, CS!)